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LITHOFACIES ANALYSIS ON THE WINDSOR LIMESTONES OF THE HAVELOCK AREA, KINGS COUNTY, NEW BRUNSWICK

by

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ABSTRACT

In an attempt to more fully understand the factors controlling the distribution of Windsor Group rocks in New Brunswick, a detailed investigation was performed on the basal Windsor limestones of the Havelock area, in northeastern Kings County. Owing to extensive limestone quarrying at Havelock, this area probably has the best exposed lower Windsor section in the entire Province.

Eight (8) distinctive limestone lithofacies representing shallow water depositional environments are present. Algal-dominated facies are most important as sources of high calcium limestone. These limestones have been the economic mainstay of the Havelock area for many years.

A regional comparison of the limestone facies developed at Havelock with those elsewhere suggests that the Moncton subbasin may have been a partially fragmented basin during at least a portion of Windsor time.

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INTRODUCTION

It is important to fully understand the various factors controlling the distribution of lower Mississippian, Windsor Group rocks in New Brunswick as they are largely represented by notable occurrences of high calcium limestone and gypsum and are intimately associated with substantial deposits of salt and potash. Limestones have also been considered as possible host rocks for base metal sulphides.

This report documents the results of a detailed investigation of depositional environments of the lower Windsor Group limestones of the Havelock area, in northeastern Kings County. It is hoped that this study will supplement a more extensive, regional study of the Windsor Group, carried out by S.R. McCutcheon (1981).

OBJECTIVES AND METHODS OF INVESTIGATION

The ultimate objective of this study is to provide a thorough evaluation and detailed inventory of Windsor limestones throughout the Havelock area, thereby enabling efficient resource management. In addition, it is hoped that knowledge gained in this investigation may be applicable to exploration for mineral deposits in other areas of the province bearing similar geologic characteristics.

To accomplish the above objectives, a few well exposed stratigraphic sections (Figure 1) were carefully measured and described. The major units were then sampled and examined petrographically using both polished and unpolished thin

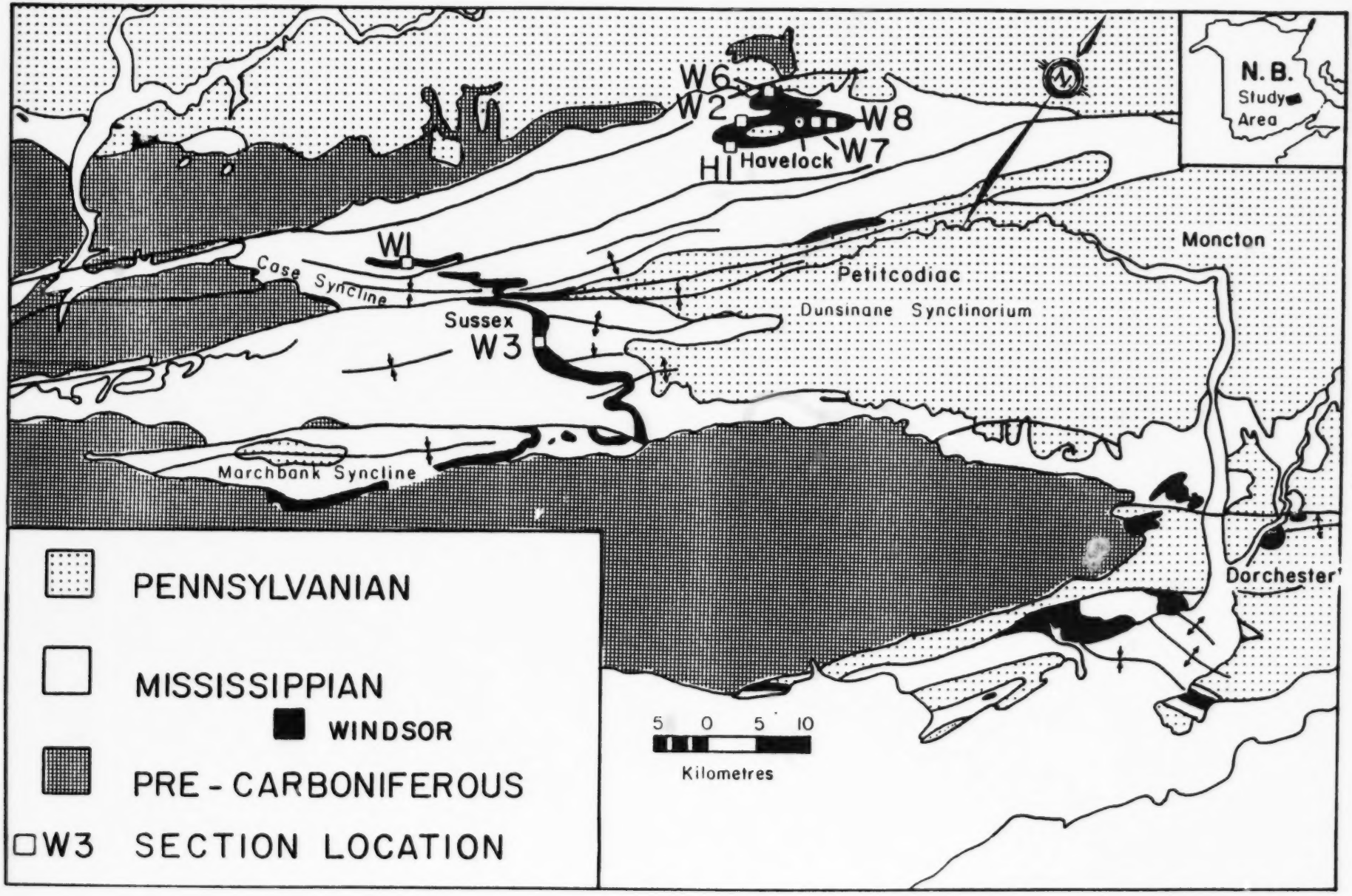


Figure 1 Distribution of the Windsor Group and the location of measured stratigraphic sections (after Webb, 1980)

sections. This petrographic data formed the basis of the interpretation of depositional environments presented herein.

LITHOFACIES RELATIONSHIPS OF WINDSOR LIMESTONES IN THE HAVELOCK AREA

Petrographic study of selected samples from detailed measured sections have made it possible to establish at least eight (8) distinctive limestone lithofacies in the Havelock area (Table 1):

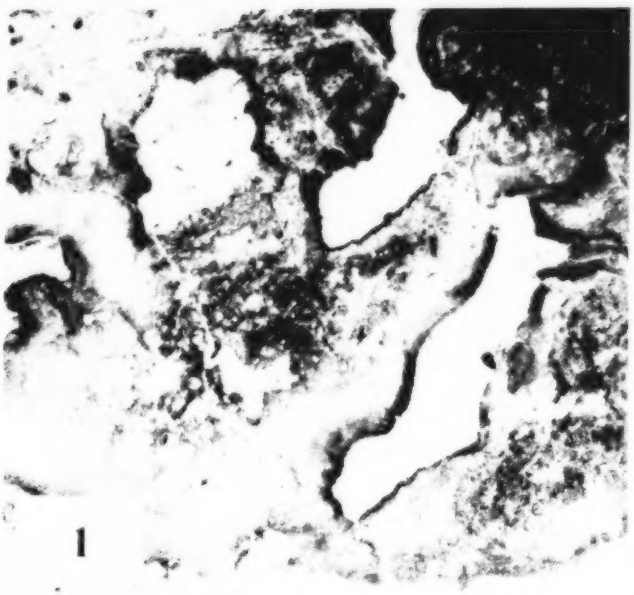
Table 1

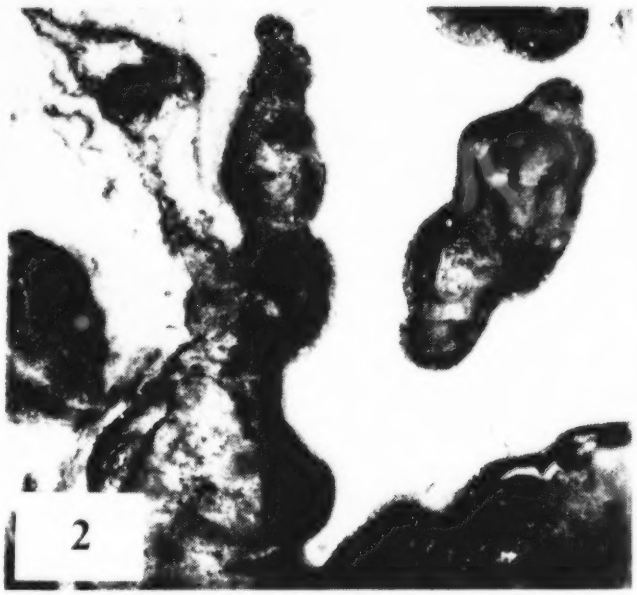
Principal Limestone Lithofacies and Interpreted Depositional Environments in the Havelock Area*

Lithofacies	Interpreted Environment of Deposition
Algal reef facies	shallow subtidal reef
Silty limestone facies	shallow subtidal inter-reef
Massive spongy limestone facies	upper intertidal
Bedded spongy limestone facies	supratidal-upper intertidal
Fibrous crust facies	supratidal
Banded limestone facies	supratidal pond
Gypsiferous laminated limestone facies	open marine to supratidal
Massive and laminated limestone facies	supratidal

These lithofacies are described in detail below and interpretations are made on their origin and depositional environment.

Refer to Figures 1 to 4; Appendix A for stratigraphic relationships.





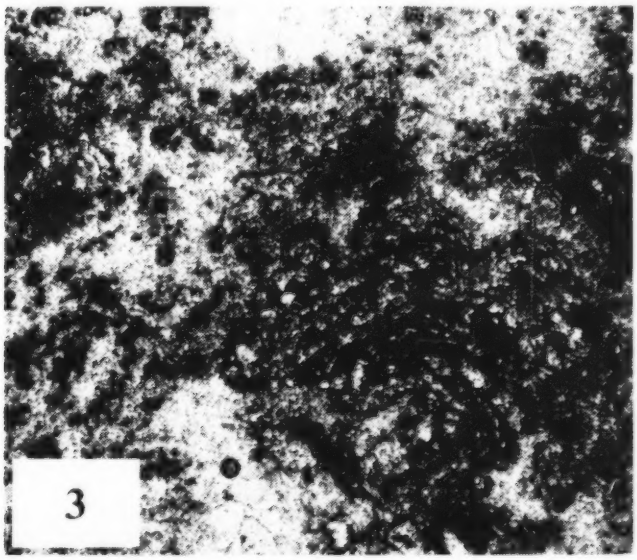


Plate 1 Algal reef facies: crustose-digitate algae in boundstone with associated calcarenites (x3)

Plate 2 Algal reef facies: crustose-digitate algae in boundstone with fringing cement lined cavities filled with calcisiltite (x3)

Plate 3 Algal reef facies: distinctive algae as micromounds possibly Girvanella (x10)

Algal Reef Facies

The algal reef facies consists of massive to thickbedded mound limestones of mudstone and calcisiltite texture with some wackestones. Minor intraclastic and pelletoidal grainstones also occur.

The most dominant characteristic of this particular facies is that it consists of distinct and sometimes coalescing mounds of irregular crustose and digitate algae, mostly micro-stromatolitic (Plate 1 and 2). The form of these algal mounds is irregular but often steep sided (Figure 2 and 3). Mounds commonly interfinger with an inter-reef bedded facies, but in most cases, boundaries are quite abrupt. The mounds range in diameter, from slightly less than 1 m to large elongate mounds of 6.5 m or more. They range in height, from about 30 cm to 1.3 m, but judging from the evidence of lateral interfingering, they probably never attained a relief in life greater than 30 cm or so above the sea floor.

Reef breccias are rare within this facies and little evidence of reef erosion has been observed so that the energy of the environment was probably quite low. However, there is some evidence of channeling.

Apart from a cryptalgal texture, there are recognizable blue-green algae similar to Girvanella, typically occurring as small micromounds within the larger mounds as part of the stromatolitic structure (Plate 3).

Some of the crustose algae are not stromatolites and may represent recrystallized red algae such as Archaelithophyllium.

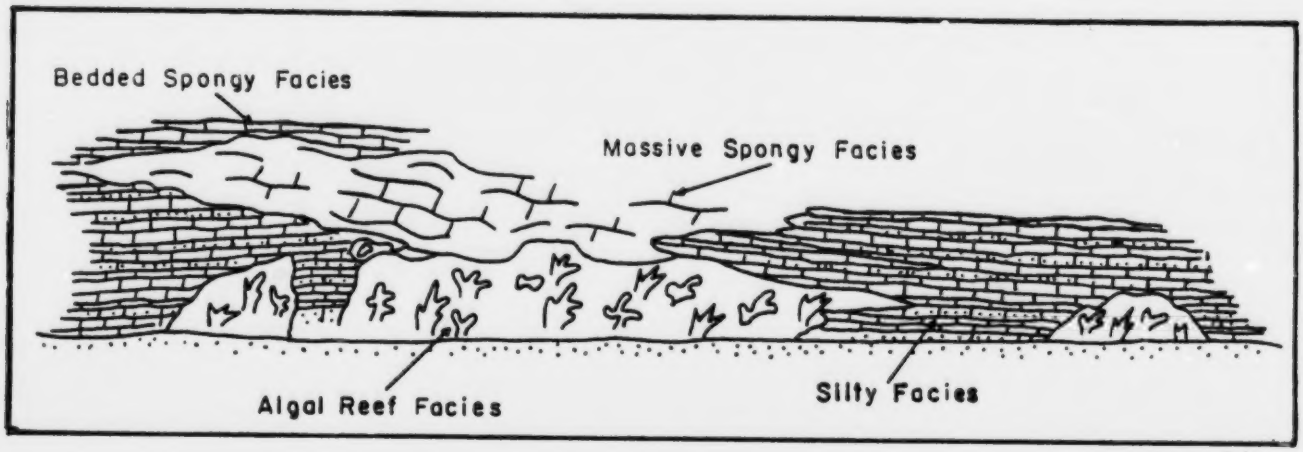
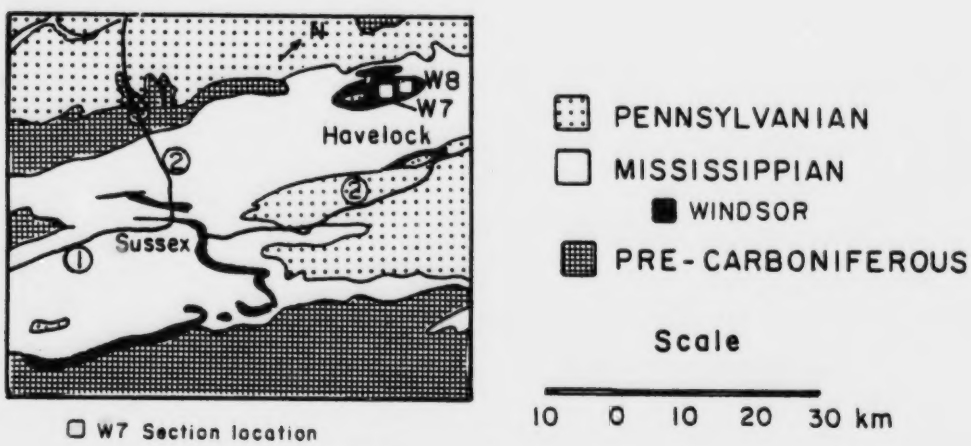


Figure 2 Reef morphology - Lower Windsor Group; section W8 - Canada Cement quarry



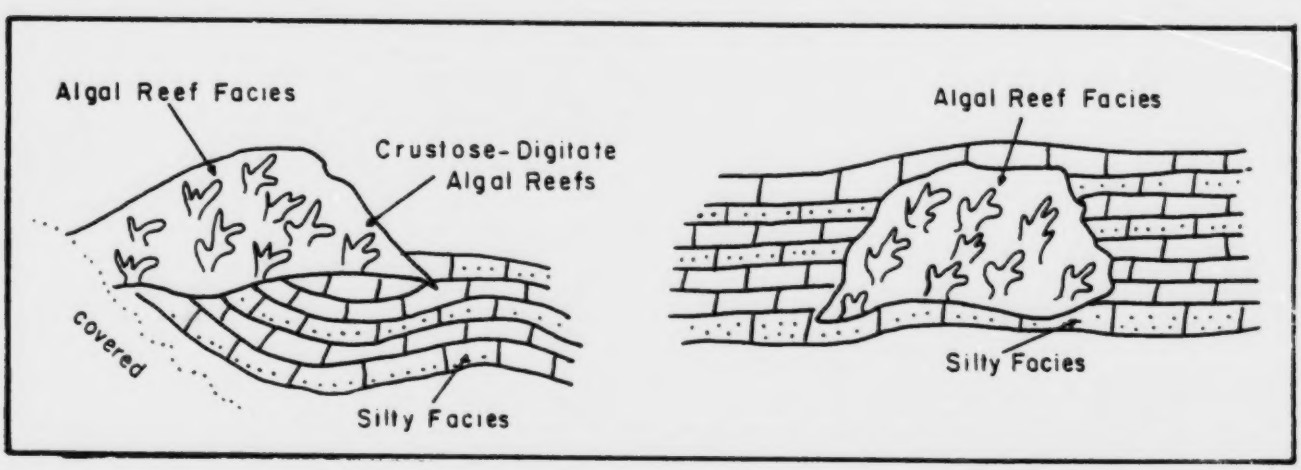
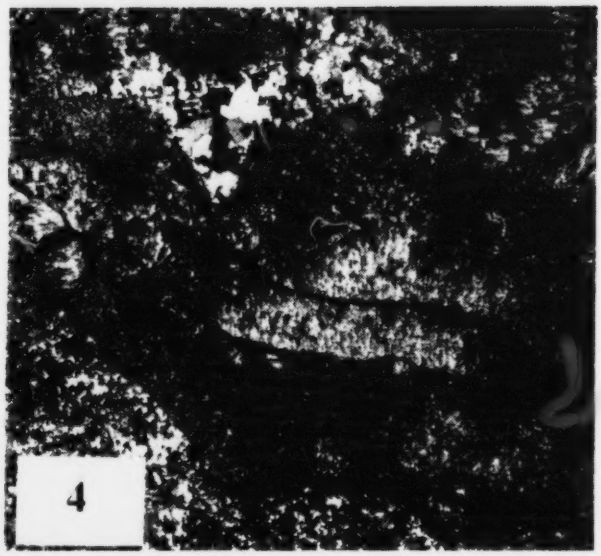


Figure 3 Reef morphology - Lower Windsor Group; section W7 - Old Havelock quarry



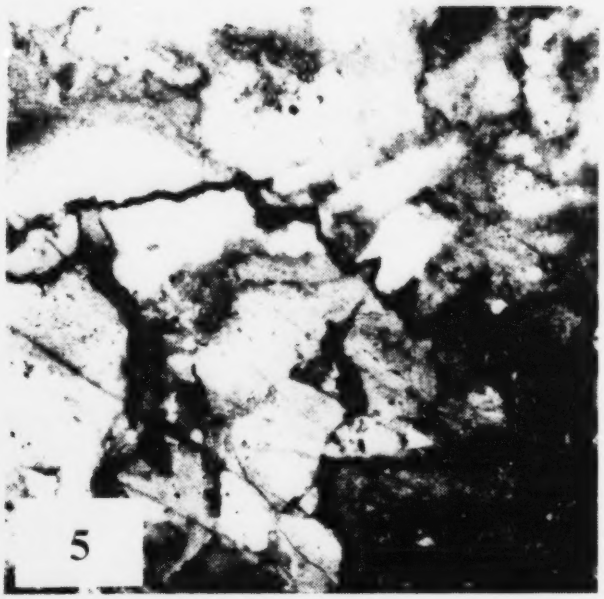


Plate 4 Algal reef facies: crustose algae in boundstone, fragmented and some cavities are filled with radial fibrous calcite cement. Other cavities have a thin rim of cement and a filling of blocky calcite cement possibly Komia (x6)

Plate 5 Algal reef facies: breccia with clasts of algal bindstone (x3)

Plate 6 Algal reef facies: large brachiopod in algal boundstone; note fibrous calcite cement lining internal wall of brachiopod (x10)

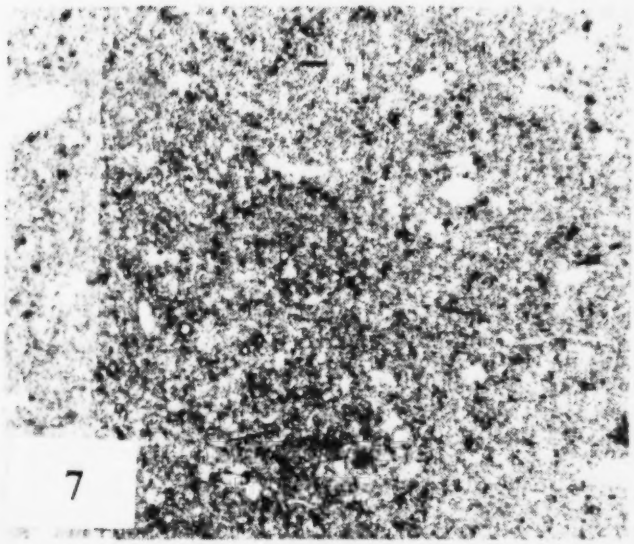
Others resemble the probable red alga Tubiphytes and the enigmatic alga Komia (Plate 4). These have been generally interpreted as algal reef-builders during the late Paleozoic (Wray, 1977).

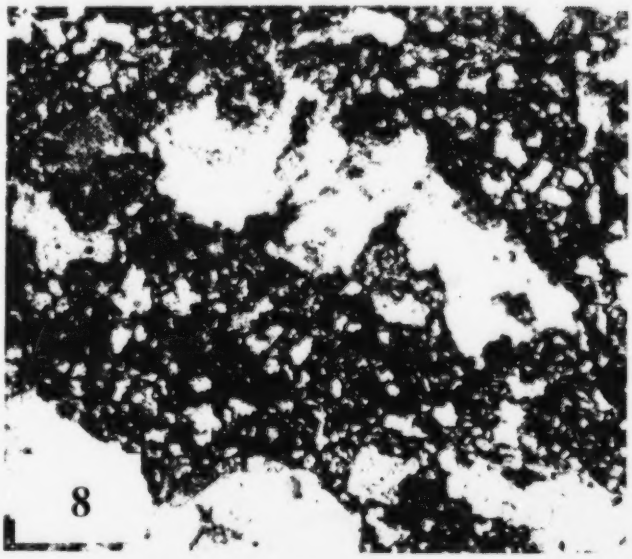
Large cavities are abundant within the algal reef framework and are frequently lined with a crust of fibrous calcite which may represent acicular marine cement. Sediments infilling the cavities are wackestones and mudstones and post-date this cement. Fenestrae are generally lacking in this facies. Hematite is common to this facies and volcanic quartz silt is minor. Some zones of breccia consisting of algal-bound sediment clasts embedded in a calcisiltite (Plate 5) have been observed. Associated fauna consists of brachiopods, gastropods and ostracods with some foraminifera. Most shelly fossils are in-situ and unfragmented (Plate 6).

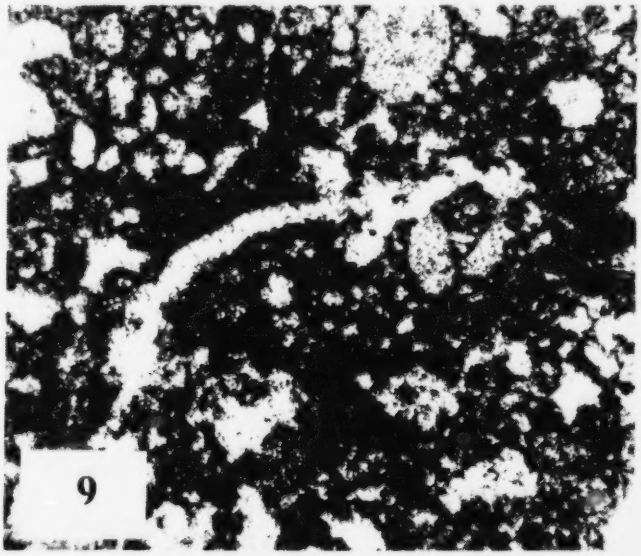
The digitate algae or branching form of stromatolites that occur within this facies suggests a subtidal to intertidal, low energy environment (Donaldson, 1976; Playford et al., 1976 and Hoffman, 1976). The association with a normal open marine fauna, the rapid lateral facies changes to an inter-reefal facies and the evidence for a very early, diagenetic marine cement as well as the general absence of fenestrae, all suggest a shallow subtidal environment of normal salinity. The crustose algae also support a subtidal reefal environment.

Silty Limestone Facies

The silty limestone facies is characterized by thin well-bedded limestone with irregular hummocky surfaces inter-







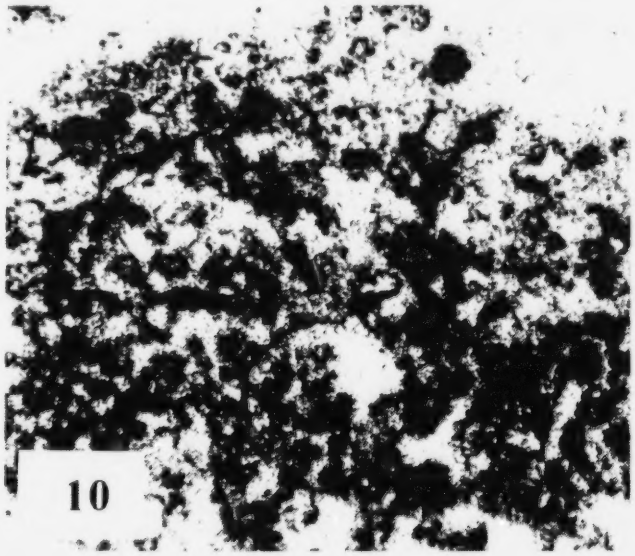


Plate 7 Silty limestone facies: note brachiopods, bryozoan and abundant small, shelly fragments in calcisiltite matrix (x20)

Plate 8 Massive spongy limestone facies: large irregular fenestrae in cryptalgal sediment of micrite and calcisiltite showing loose spongy framework (x16)

Plate 9 Massive spongy limestone facies: moldic spar well developed, probably molds of blue-green algae; matrix of spongy framework micrite-calcisiltite (x32)

Plate 10 Massive spongy limestone facies: small mound with thrombolitic texture (x8)

bedded with thin dark grey silts or shales. Limestone beds are calcisiltites and fossiliferous mudstones and wackestones (Plate 7).

Fossils are mainly very small brachiopods, ostracods, foraminifers and rare bryozoa. Some small conical shells and calcispheres also occur in this facies. Most fossils are small, thin shelled and generally unfragmented, however, locally they are disarticulated. Some intraclastic wackestone also occurs.

Fine quartz silt of volcanic origin is scattered throughout the limestones. Thin laminae and interbeds of detrital quartz are also found in association with hematite and mica.

The silty limestone facies occurs between the well defined algal mound reefs of the algal reef facies (Figure 2 and 3) and contains a fairly normal open marine fauna. The environment is therefore interpreted as a low energy, shallow subtidal inter-reef as shown by the dominance of mudstones and wackestones.

Massive Spongy Limestone Facies

Massive, porous limestones consisting of cryptalgal and partially recrystallized intraclastic-wackestones characterize the massive spongy limestone facies. Dolomitic limestone is also associated with this facies particularly in the Samphill area (W2, Figure 1).

Limestones are often vuggy with traces of irregular wavy bedding and possess a dominant cryptalgal texture with a spongy appearance caused by an irregular network of spongiostromatid laminae and algal filament molds (Plate 8 and 9). Minor thrombolitic textures also occur (Plate 10). Within this facies,

Plate 11 Massive spongy limestone facies: well developed large vugs in spongy cryptalgal limestone; note small vug with algal lamination; vugs partly filled with coarse euhedral sparry calcite (x8)

Plate 12 Massive spongy limestone facies: large vugs in spongy cryptalgal limestone with two generations of cement; an earlier finer fringing cement and a later coarse euhedral cement (x10)

fenestrae are well developed, coarse and irregularly shaped, and are filled or incompletely filled with coarse sparry cement and minor sediment (Plate 11). Hematite, fluorite and other minerals are locally found within vugs, suggestive of later movement of fluids through the limestone.

This massive spongy limestone facies forms the core of large mounds and passes abruptly and laterally into a bedded spongy facies (Figure 2). In most cases, this massive facies occurs as thick widespread units of approximately tabular form. Actual mounds within these tabular masses are often difficult to discern; however, where the facies occurs in transition to a bedded spongy facies, the mounds are easier to recognize. They are commonly 60 to 90 cm in diameter, 18 to 30 cm high and are generally convex upwards. The base of these mounds is typically flat but some of the larger mounds have a base which appears to cut the bedded spongy facies. In most cases, however, this is not an erosional feature but a lateral growth of the mound, keeping pace with the deposition of the bedded spongy facies (Figure 2). This is shown by local interfingering of the two facies.

Apart from the common occurrence of algal filament molds, some rocks within this facies have larger sub-cylindrical molds filled with microspar (Plate 9).

In some zones, late diagenetic leaching has enlarged vugs to produce a good vuggy porosity which has been only partly occluded by a late phase of coarse euhedral spar quite different from early diagenetic, blocky spar (Plate 12). Evidence indicating

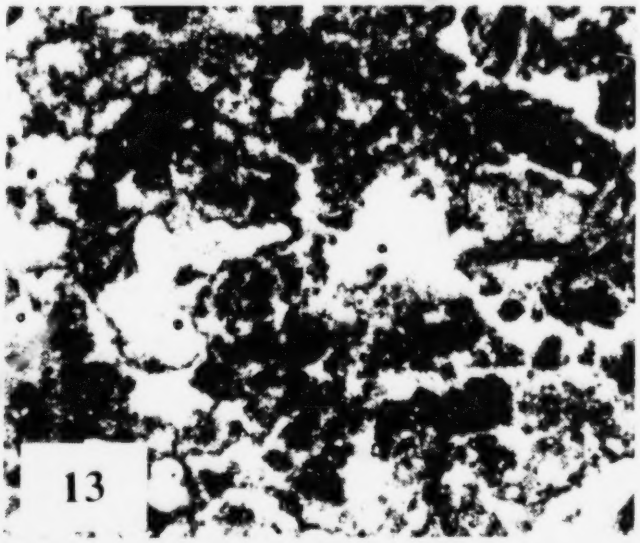


Plate 13 Bedded spongy limestone facies: brecciated cryptalgal laminae with abundant sparry cement and large algal tubes as moldic spar; some spongiostromatids (x32)

Plate 14 Bedded spongy limestone facies: spongy cryptalgal and interclastic wackestone with spongiomorphids, partly spar-filled (x20)

that the vugs were originally formed in association with algae is seen in Plate 11 where a small vug still exhibits remnants of algal laminae.

Coarsely fenestrae limestones with cryptalgal fabrics are typically intertidal with coarse fenestrae being formed by pustular algal mats (Playford and Cockbain, 1976) that are especially common in the upper intertidal zone (Hoffman, 1976). This massive spongy limestone facies is similar to Schenk's lacy limestone facies (Schenk, 1969) which always lies directly below nodular gypsum and anhydrite facies. Soft-sediment fractures interpreted as dehydration cracks and the presence of dolomite also support the concept of an upper intertidal to supratidal environment for the massive spongy limestone facies.

Bedded Spongy Limestone Facies

The bedded spongy limestone is composed primarily of red brown, bedded limestone. Bedding (3-5 cm thick) is commonly irregular, wavy or lensoid, typically passing laterally into mounds of the massive spongy facies.

Cryptalgal calcisiltites, intrasparites, wackestone and cemented breccias are common rock types to this particular facies. Algal tube molds, typically branching and molds of macroalgae are common (Plate 13). Some beds are rich in fragments of some unknown algae while others contain an abundance of spar-centered spongiomorphids (Plate 14).

Large irregular fenestrae, commonly filled with blocky sparry calcite cement but locally partly filled with sediment

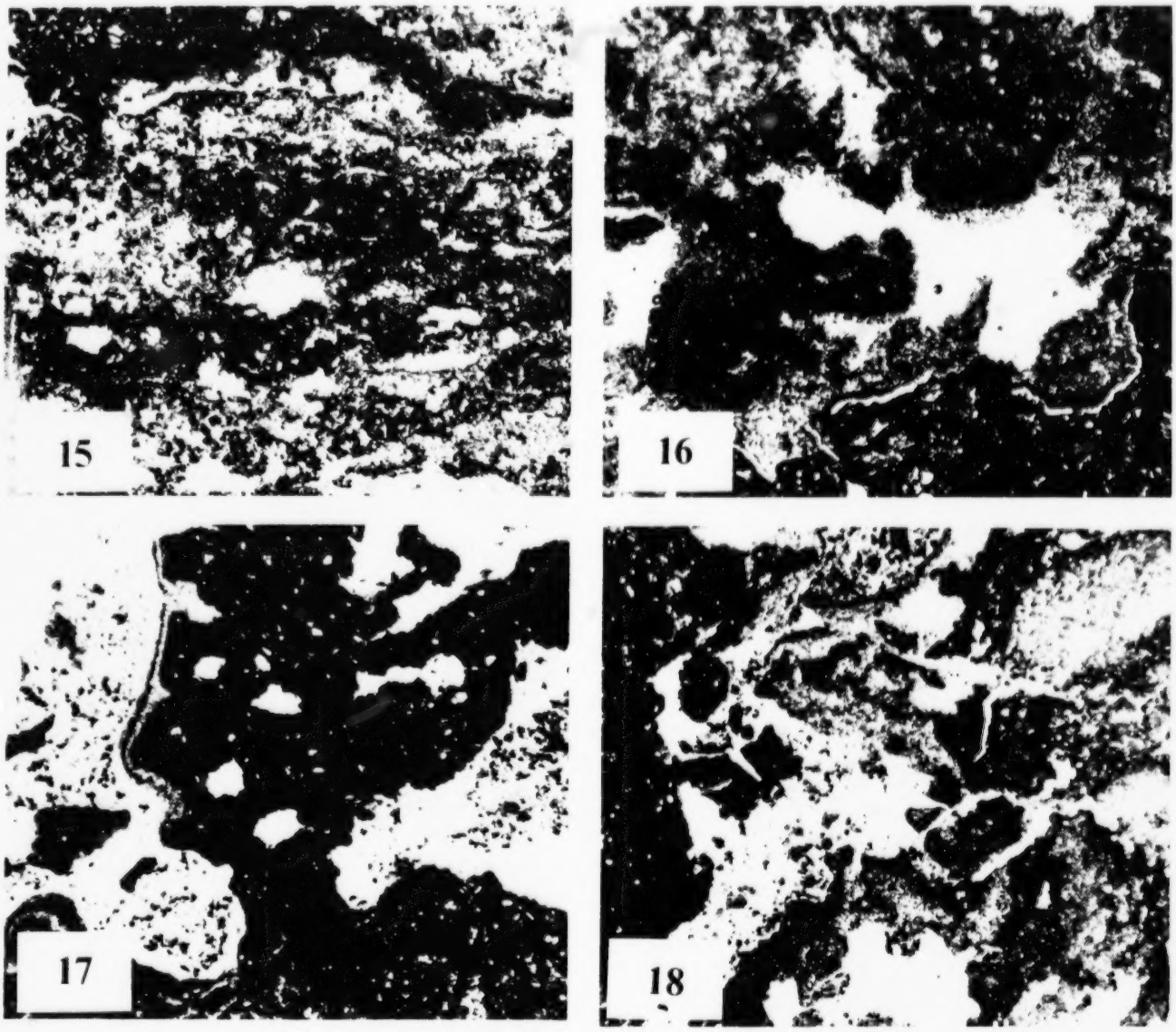


Plate 15 Bedded spongy limestone facies: cryptalgal spongy fabric with many large irregular fenestrae filled with spar; arched algal laminae apparent, roofing some larger cavities (x6)

Plate 16 Fibrous crust facies: note irregular development of fibrous crust in cryptalgal mudstones. Crusts mostly line large cavities which are partially sediment filled (x8)

Plate 17 Fibrous crust facies: large cavities in cryptalgal mudstone, lined in part by two layers of fibrous cement separated by an algal coating; cavities are sediment filled, largely recrystallized and rich in pyrite (x27)

Plate 18 Fibrous crust facies: cryptalgal mudstone, large cavities partially lined with fibrous calcite cement and slight brecciation associated with shrinkage cracks (x25)

recrystallized to microspar are found within this facies. Some large, flat cavities are floored with red clay and silt and filled with spar while others are roofed by algal mat stromatolites (Plate 15). Minor volcanic quartz silt and thin irregular seams or lenses of green clay are distributed throughout. Foraminifera occur locally.

The depositional environment for this particular facies probably consisted of shallow water, dominated by algal mats with some problematic macroalgae and widely separated stromatolitic algal mounds. The algal bearing units which are irregular and leaf-like, partially trapped mud which was later recrystallized. The irregular stacking of algae resulted in the formation of voids which were later filled with sparry calcite cement.

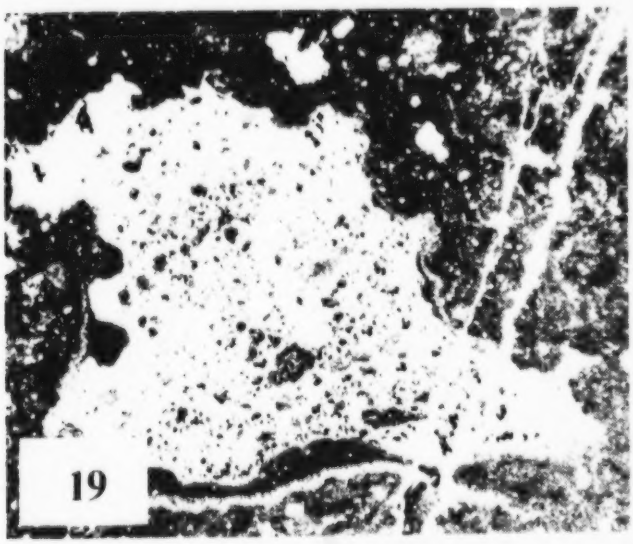
The presence of algal mats, abundant fenestrae and brecciation suggest a supratidal to upper intertidal environment. Identical facies from the Triassic Moenkopi Formation of Nevada (Bissel, 1970) have also been interpreted as supratidal algal mats.

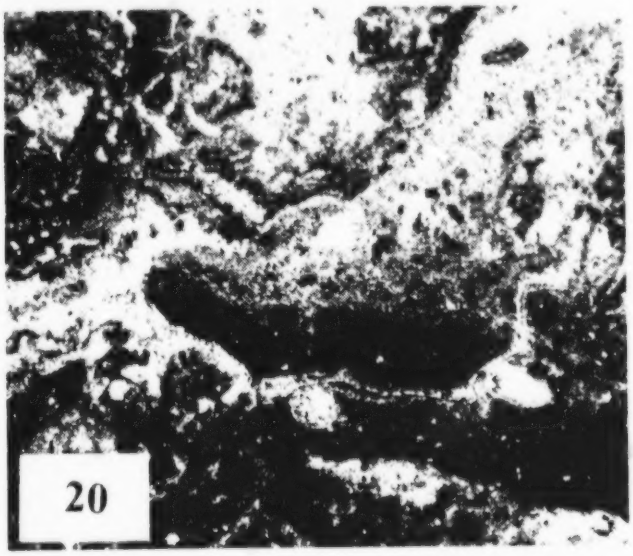
Fibrous Crust Facies

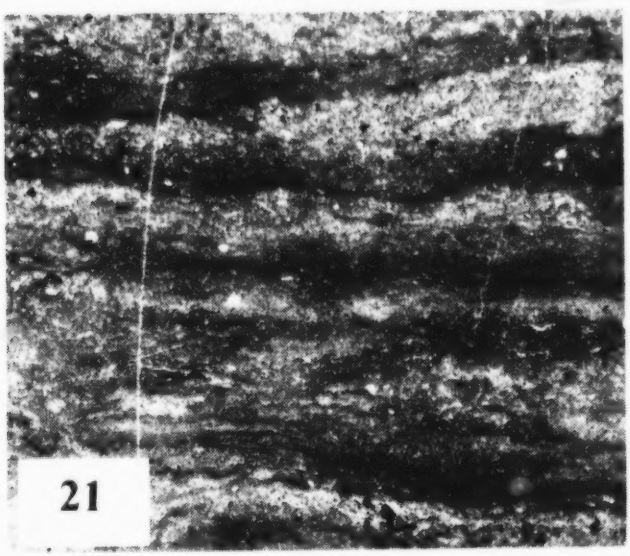
Interbedded, grey, crumbly, thinly-bedded limestones and grey shales with some plant fragments typify the fibrous crust facies.

The dominant texture of this facies is a partly brecciated intraclastic wackestone and mudstone with scattered volcanic quartz silt and some laminae rich in detrital quartz and feldspar silt. Parts of the wackestone appear to be cryptalgal with a thrombolitic texture and well developed fenestrae.

Fibrous calcite crusts are irregularly developed throughout







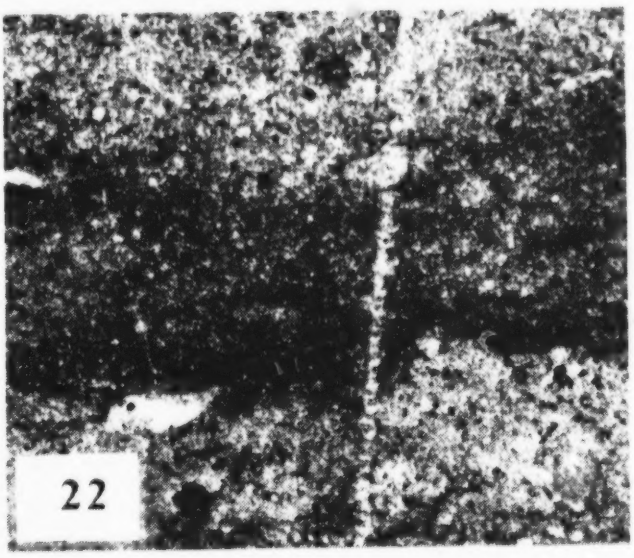


Plate 19 Fibrous crust facies: large cavity with fibrous crust lining and later algal growths post dating the lining cement (x23)

Plate 20 Fibrous crust facies: fibrous crusts associated with apparent algal reproductive bodies suggest that the crust may be algal in origin (x20)

Plate 21 Banded limestone facies: note abundant pyrite and irregular banding (x6)

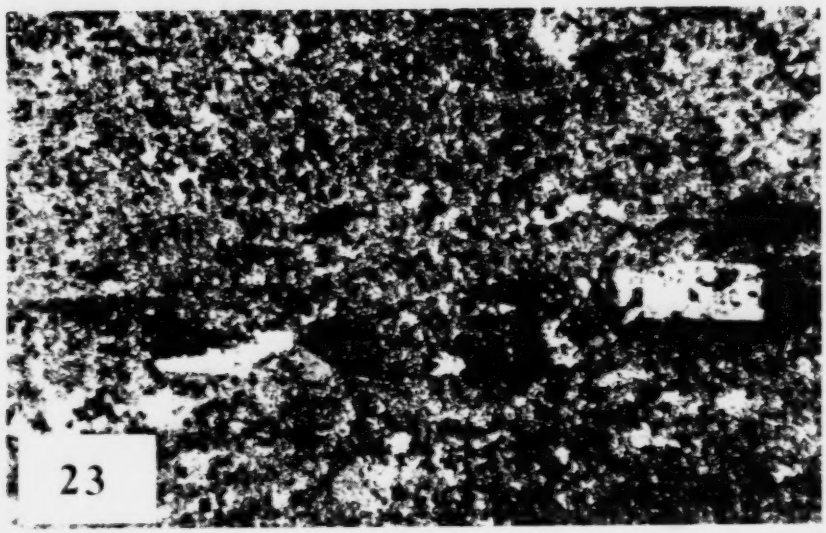
Plate 22 Banded limestone facies: note abundant pyrite in lighter colored bands and also partially infilling shells (x20)

the sediment but usually appear to line cavities (Plate 16). Cavities are for the most part filled with neomorphic spar or microspar and pyrite commonly replaces an original mudstone or wackestone fill (Plate 17). Dehydration cracks partly filled by sediment or sparry calcite cement (Plate 18), are common.

Most cavities associated with this facies were probably formed as part of an irregular stromatolitic framework in an intertidal or supratidal environment that was subjected to periodic wetting and drying. They were lined with fibrous calcite and some of these were probably kept open long enough for the growth of algal encrustations on the walls before being filled with sediment (Plate 19). In some cases, an alternating succession of several phases of algal growth and fibrous crust development can be recognized before the cavity became filled with sediment. There is also evidence which suggests some of the fibrous crusts may actually be phylloid algae, as apparent reproductive bodies have been observed in one case (Plate 20).

Banded Limestone Facies

This facies, referred to as the banded limestone facies, is characterized by irregular light and dark limestone in bands, 1-2 mm thick (Plate 21). Lighter coloured layers consist of coarse neomorphic sparry calcite with abundant scattered crystals and patches of pyrite (Plate 22). Some fenestrae are irregularly developed but are not flattended in the plane of the bedding. This facies is locally gypsiferous and is closely associated with beds which have traces of plant material. Ostracods are common throughout.



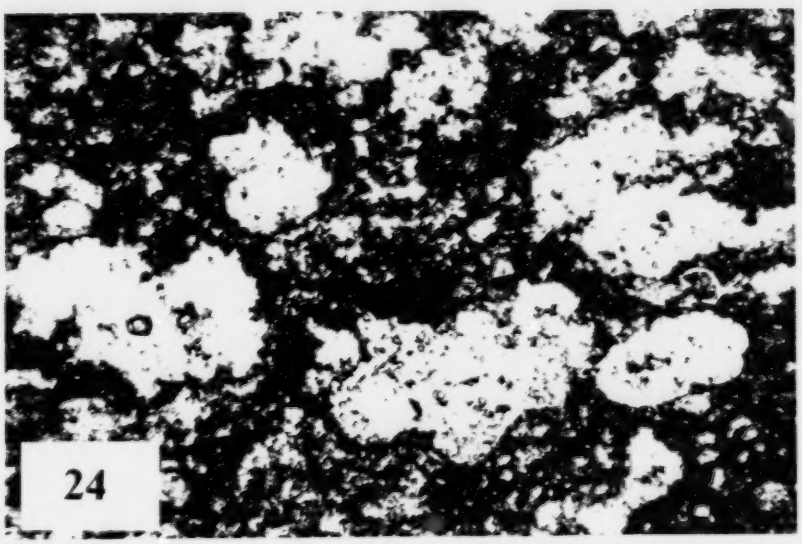


Plate 23 Gypsiferous laminated limestone facies: gypsum after anhydrite, partially corroded, with abundant scattered halite crystals also partially corroded (x32)

Plate 24 Gypsiferous laminated limestone facies: gypsum pseudomorphs after anhydrite, partially corroded in a cryptalgal matrix (x20)

The dark layers of this facies consist of micrite or calcisiltite interrupted by irregular patches of neomorphic spar. A vague cryptalgal texture is present. Widely distributed ostracod shells and pyrite occur, but both are much less abundant than in the lighter coloured layers. Pyritization took place prior to the formation of the sparry calcite cement.

This particular facies is not common throughout the Havelock area and occurs near the top of the stratigraphic sections where it has been observed. The banding suggests intermittent and periodic sedimentation. The close association with plant fragments and ostracods together with abundant pyritization and the slightly gypsiferous nature of the dark layers suggest a supratidal pond environment with periodic flooding and evaporation. The absence of dehydration features suggest the pond was more or less permanent and that it was not intertidal.

Gypsiferous Laminated Limestone Facies

Dense laminated limestone with minor wispy clay laminae and minor patches of gypsum typify the gypsiferous laminated limestone facies. This facies possesses a dominant cryptalgal texture and contains sparsely scattered, fragmented shells (brachiopods and ostracods) and dark organic blebs which are probably derived from algal fragments (Plate 23). Lamination is caused mainly be bands of mudstone and wackestone rich in fenestrae which generally are filled with sparry calcite cement or gypsum. Some of the more nodular patches of gypsum

with sub-rounded boundaries are probably displacive anhydrite nodules now replaced by gypsum. Small cubic crystals of halite occur as inclusions in the gypsum or in sparry calcite cement, most commonly within the nodules or fenestrae (Plate 24).

The originally displacive anhydrite crystals and nodules and displacive halite indicate a transition from an open marine shallow subtidal environment to a more saline supratidal, sabkha environment. It is noteworthy that the sparse fauna that is associated with this facies is mostly fragmented and, therefore, probably has been transported from a more open marine reefal environment into this supratidal environment.

Laminated and Massive Limestone Facies

Interbedded, laminated to thin- and thick-bedded limestone characterize this facies. Thick-bedded units are vuggy, with shaly or laminated limestone clasts. Laminated units are generally dark, bituminous, irregularly cross-bedded and rarely dolomitic. Textures are vaguely cryptalgal and are extensively recrystallized with coarse neomorphic spar. Fenestrae with spongy calcite cement occur locally. Some layers of mudstone, possess dehydration features. In most sections, this particular facies is near the top of the Windsor Group.

The complete absence of any fauna, possible algal mat structures and the good evidence for dessication suggest a supratidal environment.

FACIES INTERPRETATION IN RELATION TO THE DEPOSITIONAL BASIN IN THE HAVELOCK AREA

Figure 4 summarizes the recognized limestone facies and the sequence of depositional environments in the Havelock area and their lateral relationships. A number of tentativ conclusions may be drawn from these observations.

1. The deposition of the Windsor limestone in the Havelock area began with a rapid marine transgression over coarse fluvial clastics of the Moncton Group followed by a slow general regression as the depositional basin filled. The basal units of the Windsor Group in this area are mainly subtidal limestones. These are followed by mainly intertidal facies, then supratidal and deltaic and finally fluvial facies.

   The best and most continuously exposed stratigraphic section in the Havelock area is at the Samphill quarry (W2, Figure 1 and 4) where the overall regression as described above is evident. At this locality, interbedded deltaic to tidal flat and fluvial clastics and supratidal carbonates can be observed near the top of the section.

2. Even within the limited areal extent of the Havelock outcrop area (Figure 1) it is possible to discern lateral facies changes within the Windsor limestones. In the lowermost unit where digitate and crustose algal reefs are well developed, the thickest and best developed reefs are in Springhill section (W6, Figure 1 and 4). To the east and south, these reefal units thin and pass laterally

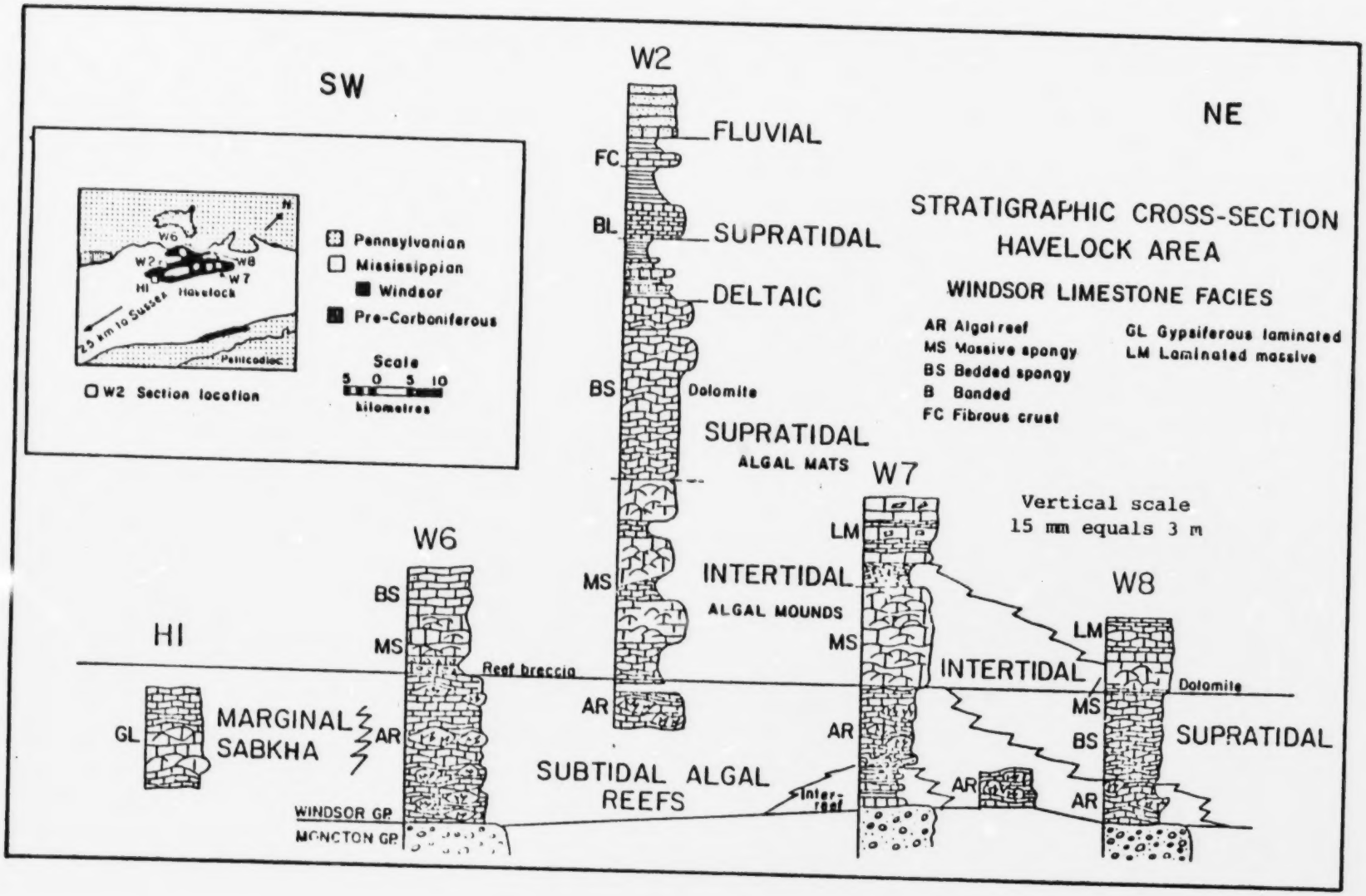


Figure 4 Stratigraphic cross-sections of the Windsor Group in the Havelock area

into a bedded algal mat facies near the Canada Cement Quarry (W9, Figure 1 and 4) and into a gypsiferous laminated limestone facies near Thornbrook (H1, Figure 1 and 4).

Algal reefs are almost certainly subtidal in origin whereas the algal mat and gypsiferous facies are almost certainly supratidal. There is a strong suggestion that the basin was deepening to the northeast, however, this may reflect a local rather than a regional trend.

ECONOMIC GEOLOGY

High Calcium Limestone

Limestone has been quarried from the Havelock area for over 50 years and at present, two quarries are operating. One quarry, operated by Havelock Lime Works Ltd., serves as a source of limestone for the manufacture of lime, quicklime, agricultural lime and crushed stone while the other is operated by Canada Cement (Lafarge) Limited where limestone is used in the manufacture of cement.

In order to relate the distribution of zones of high calcium limestone to individual limestone facies recognized in the Havelock area, a number of samples were randomly selected from each lithofacies and analysed for dolomite, calcite and insoluble residues. All facies except the silty limestone (inter-reef), fibrous crust, banded limestone and gypsiferous laminated limestone facies are relatively pure in calcite. The silty limestone facies is exceptional in that insolubles, mostly quartz, are about 15 to 20 percent.

Dolomite, although largely restricted to the massive spongy facies in the Samphill quarry, also occurs erratically throughout the massive and laminated facies near the old Havelock and Canada Cement quarries. Insolubles of most facies are largely quartz and clay minerals with some micaceous minerals.

RELATION OF WINDSOR LIMESTONES OF THE HAVELOCK AREA TO THOSE ELSEWHERE IN THE MONCTON SUBBASIN

In order to briefly compare Windsor limestone facies developed at Havelock with those from other parts of the Moncton subbasin, stratigraphic sections at Parleeville (W1, Figure 1) and Sussex Corner (W3, Figure 1) some 40 km southwest and 30 km south of Havelock respectively, were measured, sampled and petrographically examined.

At Parleeville, basal Windsor limestones are represented by a subtidal algal reef facies consisting of digitate and crustose algae very similar to those in the Havelock area. The strata above the algal reef facies are sandy limestones and calcareous sandstones referred to as the sandy facies and the limestone is similar to the bedded spongy limestone facies of the Havelock area (Figure 5). These strata are locally folded and algal reefs can be seen to have been growing on what appears to be an eroded surface which cuts down into folded beds (Figure 6). Three possible explanations are considered to account for this peculiar association. One explanation suggests that uplift, folding and subsequent erosion, preceded by deposition of wedges of clastic sediment,

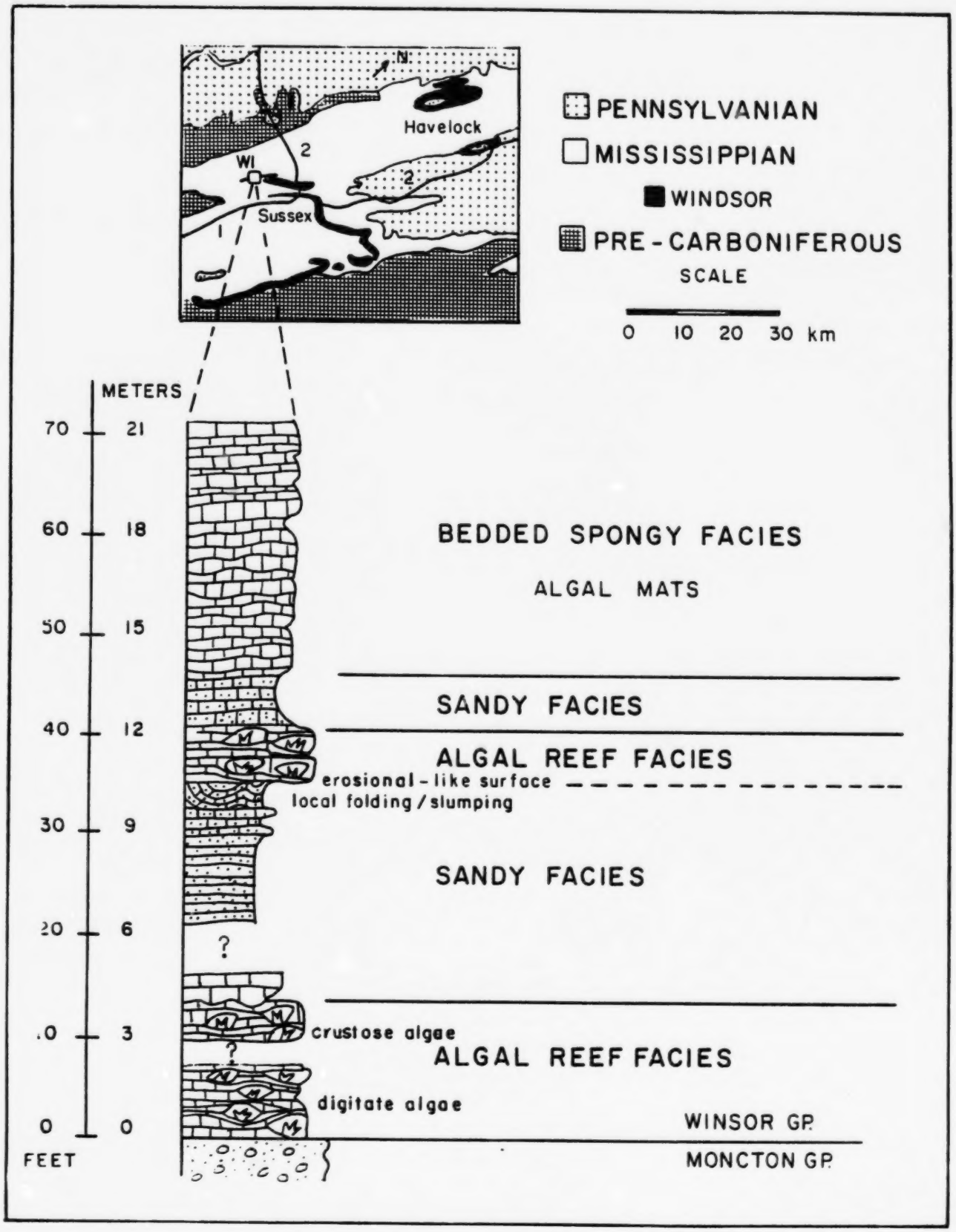


Figure 5 Stratigraphic section of Lower Windsor Group near Parleeville - W1

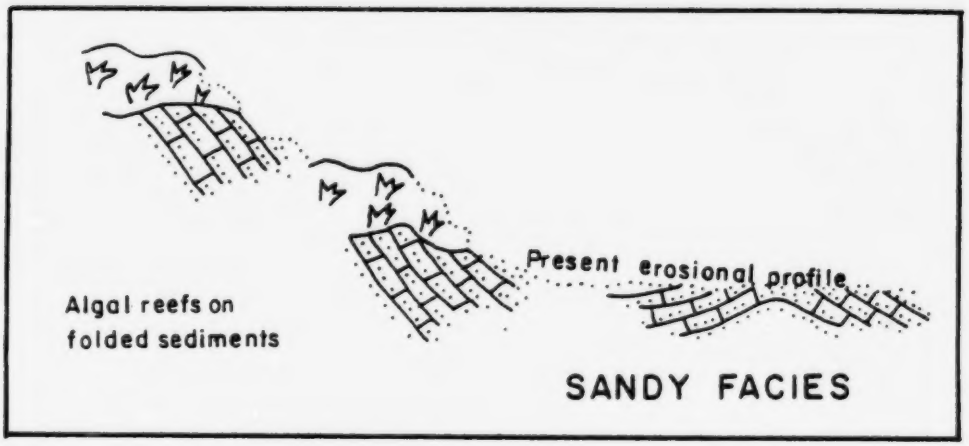


Figure 6 Profile of stratigraphic section W1, near Parleeville Stream

occurred locally since there is no evidence for this event in the Havelock area which is more or less on regional strike. This "unconformity" must have been followed by second transgressive episode due to the subsequent development of yet another period of algal reef growth over the irregular topographic surface. A second explanation considers the folded beds to be simply a result of local slumping and lateral growth of the algal reef facies keeping pace with the deposition of the sandy facies. A third offered is a compromise of the first and second explanations suggesting minor uplift, slumping of resultant clastics and overstepping by algal reefs. The writers admit that more detailed study is necessary before this problem can be resolved.

Windsor outcrop at Sussex Corner (W3, Figure 1) is a thin limestone section (Figure 7) containing abundant plant fragments. This strata rests discordantly on conglomerate of the Moncton Group and consists of extremely contorted thin limestone which have been folded and thrust from the south. Rapid thinning and thickening of many beds, dislocated clasts together with the local nature of some folds sandwiched between flat beds suggest soft-sediment slumping rather than tectonic folding, especially as this phenomenon is so local in nature.

The general similarity of the succession of limestone and evaporites of the Windsor Group, throughout the Moncton subbasin, has led previous workers to conclude a single large original depositional basin now fragmented

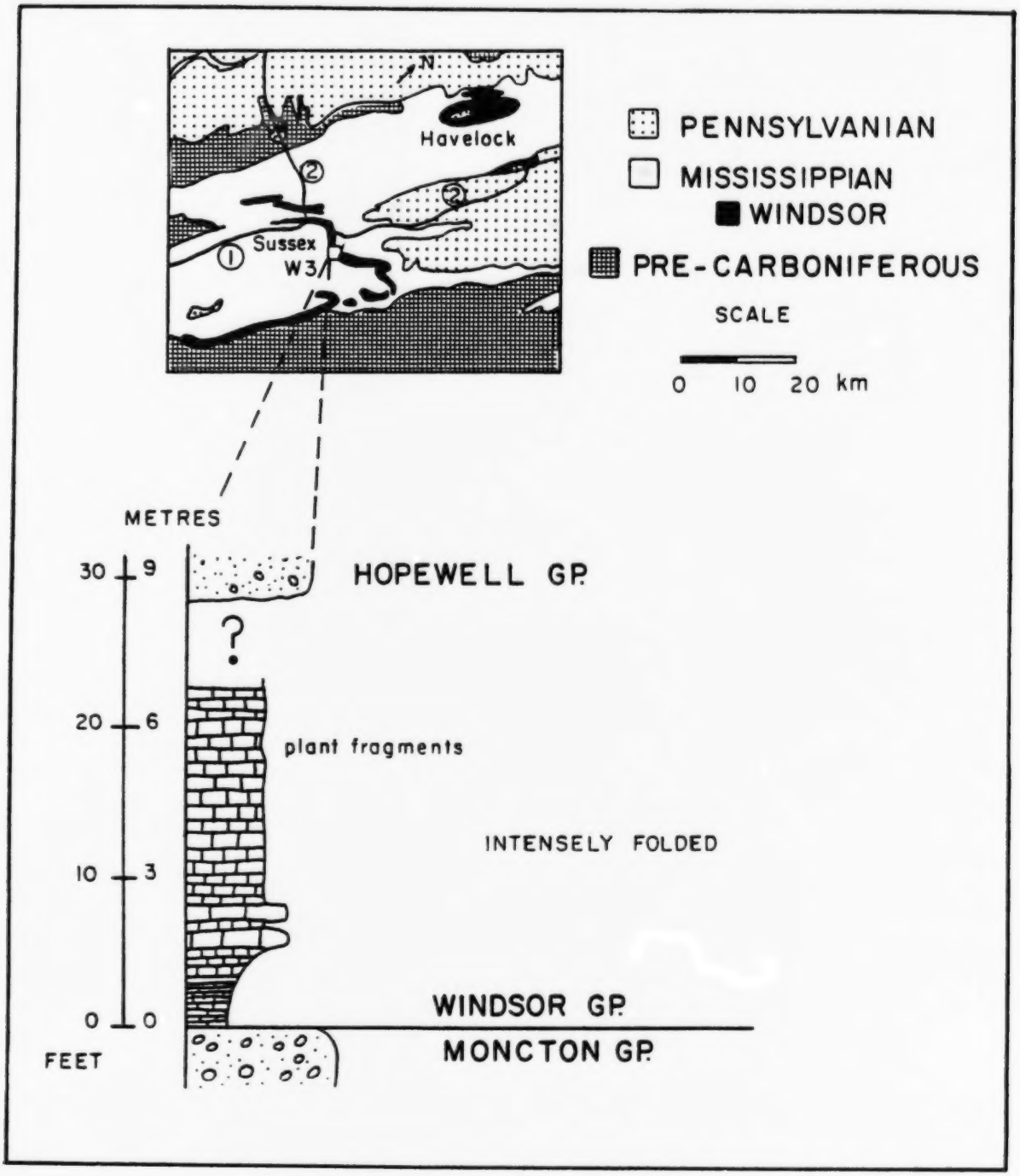


Figure 7 Stratigraphic section of Lower Windsor Group at Sussex Corner - section W3

by folding or faulting into separate tectonic units. More specifically, these units include the Marchbank Syncline, the Dunsinane Synclinorium, the Case Syncline and the Havelock Syncline (Figure 1). On the basis of the above findings, it would appear that there is scant evidence for this conclusion. It is therefore suggested that the Moncton subbasin probably comprised a number of separate or interconnected basins during at least a portion of Windsor time. While admitting that more detailed work is necessary on facies of the other parts of the Moncton subbasin before any conclusive deductions can be drawn, the following observations suggest that the subbasin may have been a partially fragmented basin even in Windsor time:

1. Limestone exposed at Parleeville tends to indicate this was an area close to an upland block (probably the Lower Paleozoic) to give the wedge of volcanic quartz rich sandstones (sandy facies) within the lowermost unit of Windsor strata.
2. There is some evidence for syndepositional slumping at Sussex Corner, possibly Parleeville and at section W7 (Figure 4) in Havelock area, suggesting local tectonic movements along the edges of fault blocks during Windsor time.

The evidence, therefore, suggests local tectonic movements in various parts of the Moncton subbasin contemporaneous with a considerable amount of volcanic activity (Roulston and Waugh, 1981). Tectonic activity associated with this volcanism may have been responsible for the development of local basins resulting in the differences seen in local basal stratigraphy.

CONCLUSIONS

1. Algal features in most limestone facies throughout much of the Havelock area support a shallow water environment of deposition.

2. Interpretation of limestone facies at Havelock suggest the shallowing of a local basin to the southwest.

3. The main limestone facies identified in the Havelock area, with the exception of the silty limestone, fibrous crust, bedded limestone and gypsiferous laminated limestone facies are characterized by relatively pure limestone (95 to 99 percent $CaCO_3$) with very minor amounts of quartz, clays and mica. The algal reef, massive spongy limestone and bedded spongy limestone facies represent the thickest high calcium strata with the most consistent distribution throughout the entire depositional basin. It would appear, therefore, that the future development of limestone resources in the Havelock area will no doubt be largely governed by various restraints to efficient quarrying practices rather than by stone of poor quality.

4. Dolomite is rare throughout most of the Havelock area, as it is in other parts of the Moncton subbasin, occurring as erratic beds and pockets only near the southern and western extremities of the outcrop area. Near the old Havelock quarry, minor dolomite was identified in the massive and laminated limestone facies, however, it is much more abundant in the massive spongy limestone facies of the Samphill area.

5. Limestone facies identified at Havelock and various parts of the Moncton subbasin suggest local tectonic movements were largely responsible for the development of separate or interconnected basins, accounting for differences in the local basal Windsor stratigraphy.

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APPENDIX A

LITHOLOGS OF STRATIGRAPHIC SECTIONS W2, W6, W7 and W8

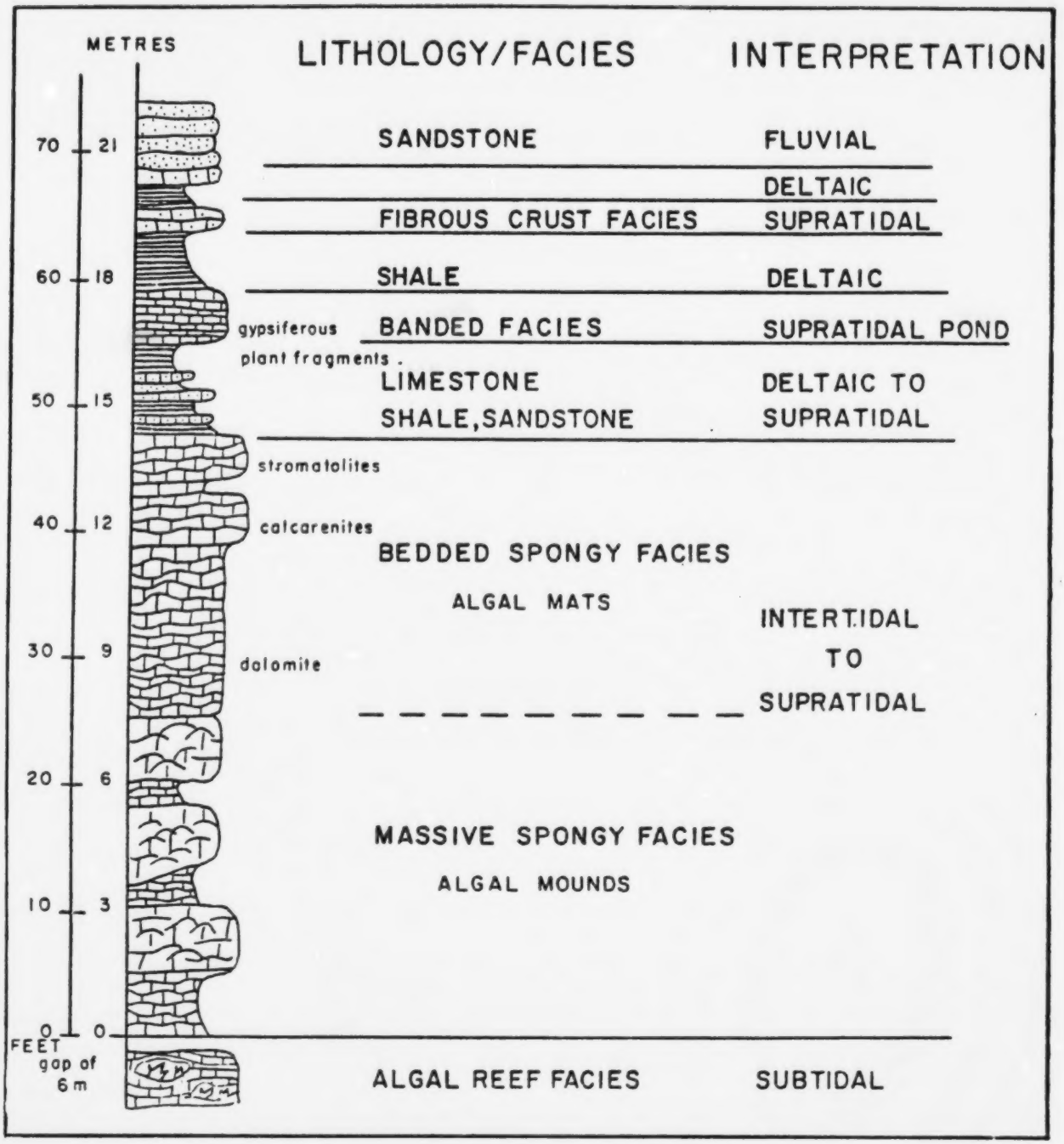

Figure 1 Stratigraphic section of Lower Windsor Group at Samphill - section W2

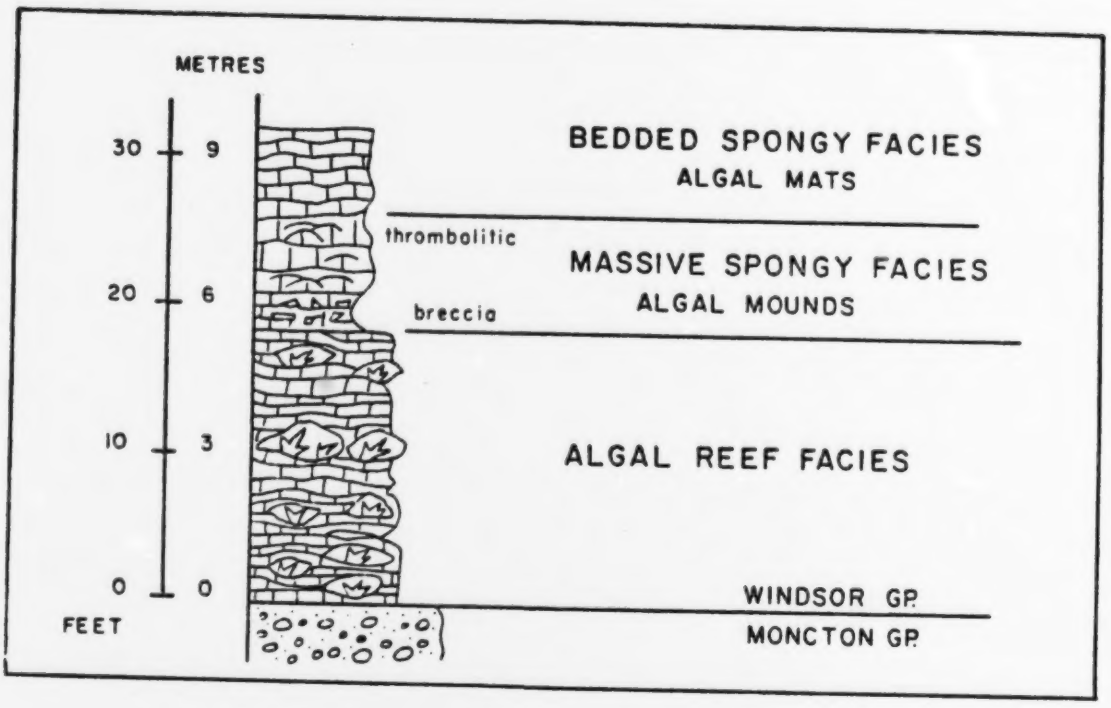

Figure 2 Stratigraphic section of Lower Windsor Group at Springhill - section W6

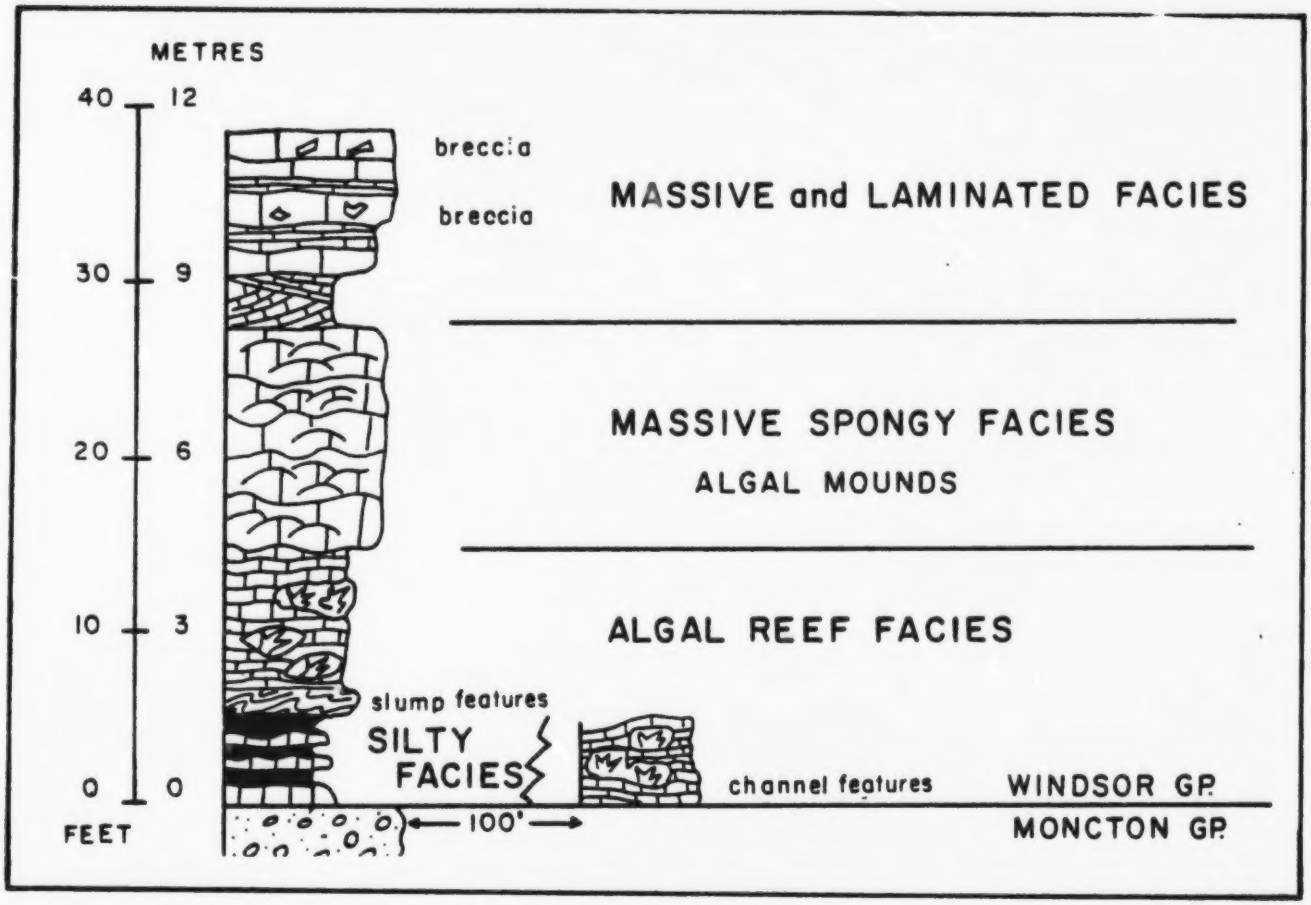

Figure 3 Stratigraphic section of Lower Windsor Group at Old Havelock quarry - section W7

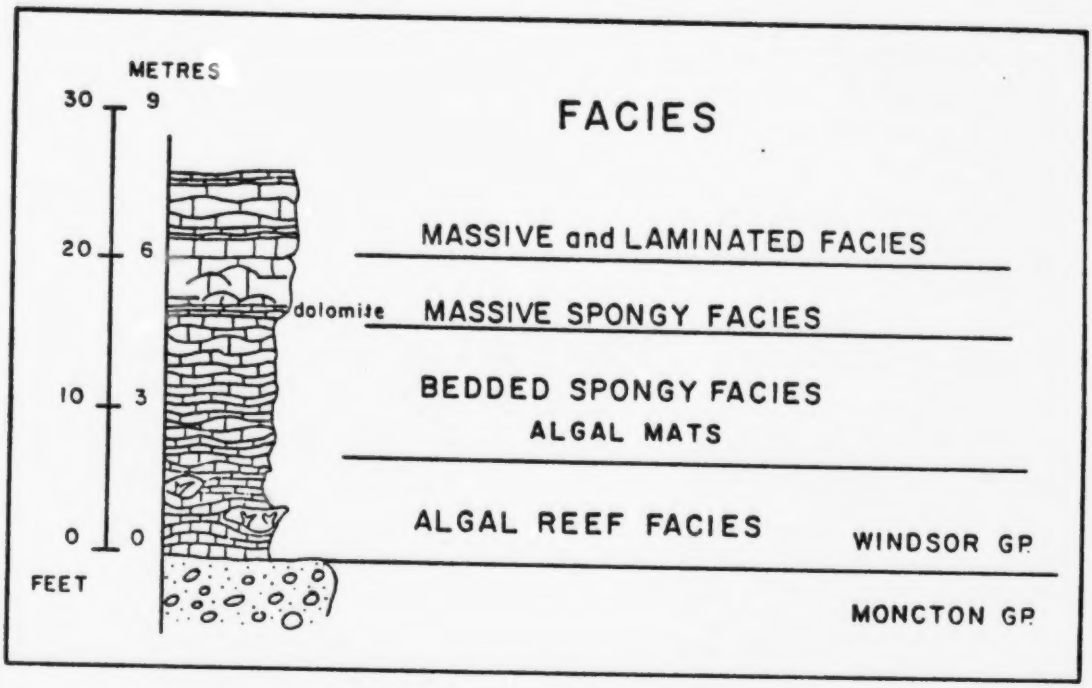

Figure 4 Stratigraphic section of Lower Windsor Group at Canada Cement quarry - section W8